

704920020016 US1

1/30

HARE ET AL

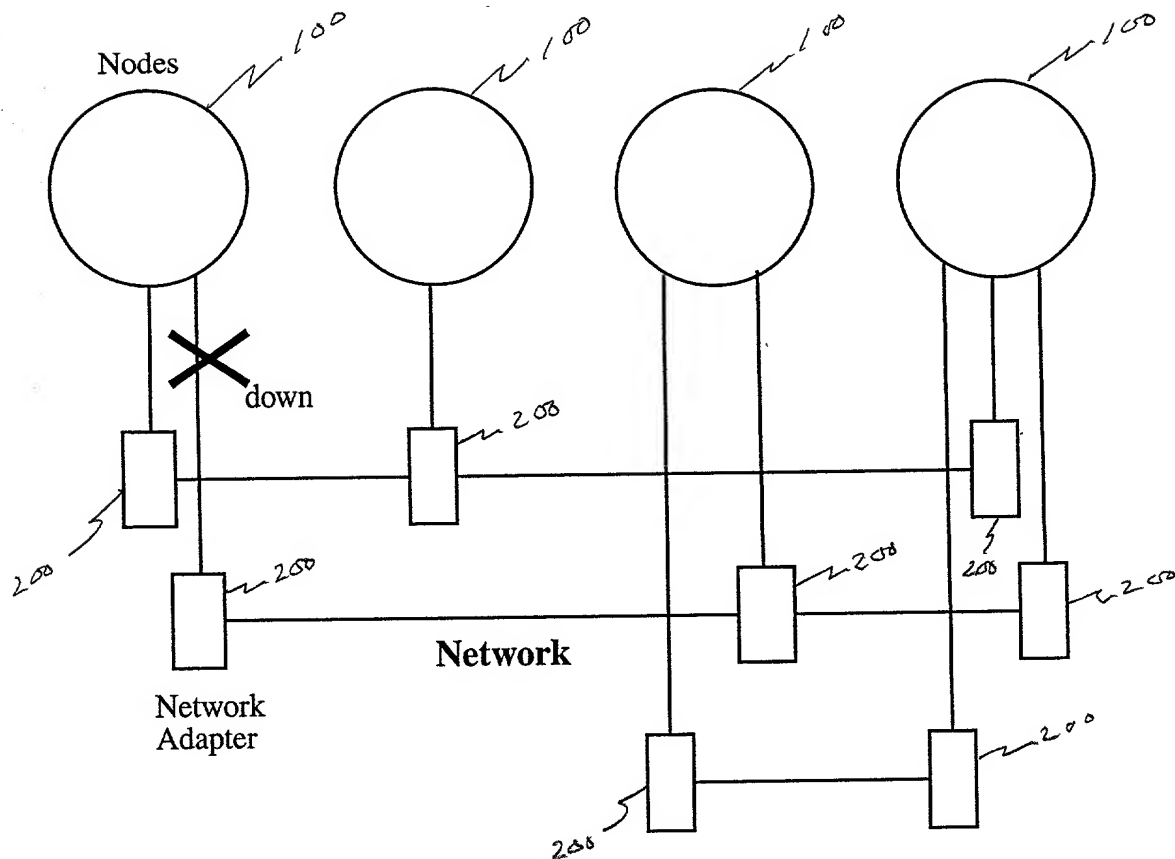


Figure 1: Nodes and physical connectivity

2/30

PON 920020016451

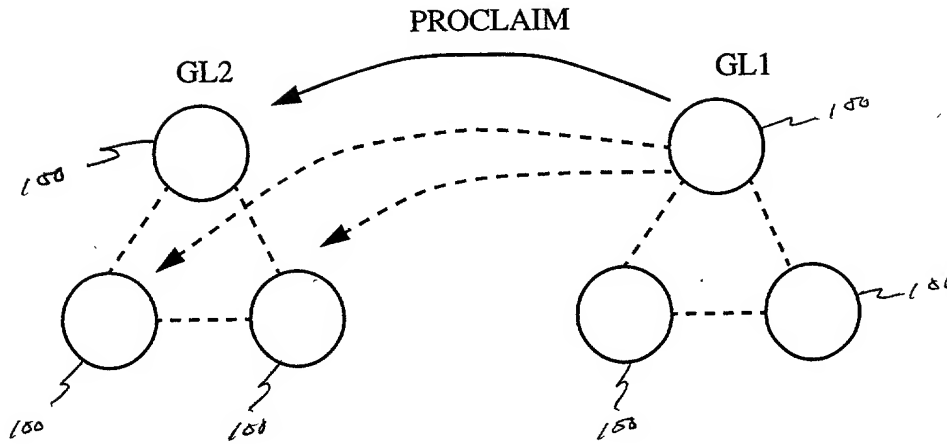


Figure 2a) JOIN Protocol: PROCLAIM message

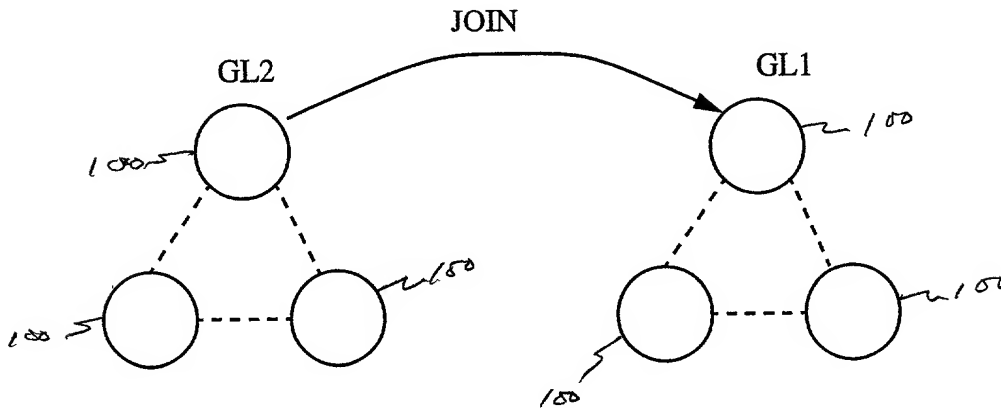


Figure 2b) JOIN Protocol: JOIN message

3/30

Pou 920020016451

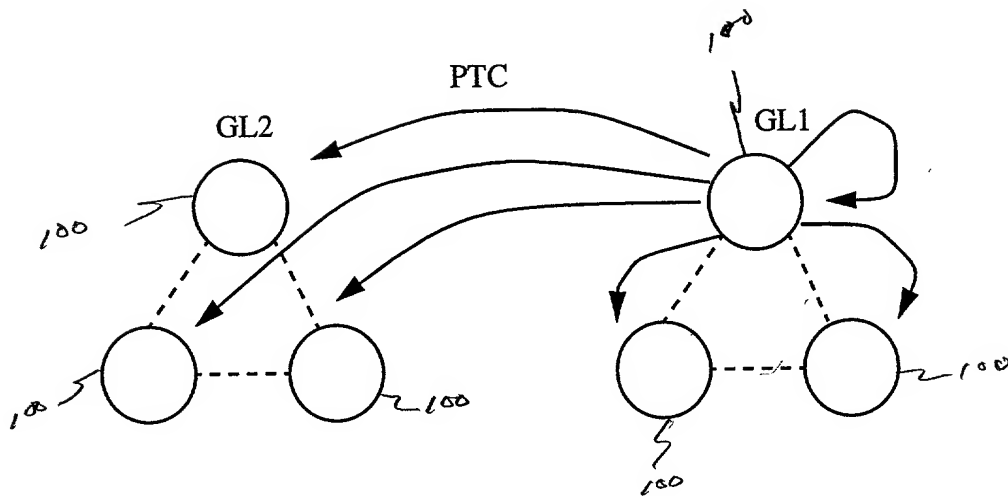


Figure 2c) JOIN Protocol: PTC message

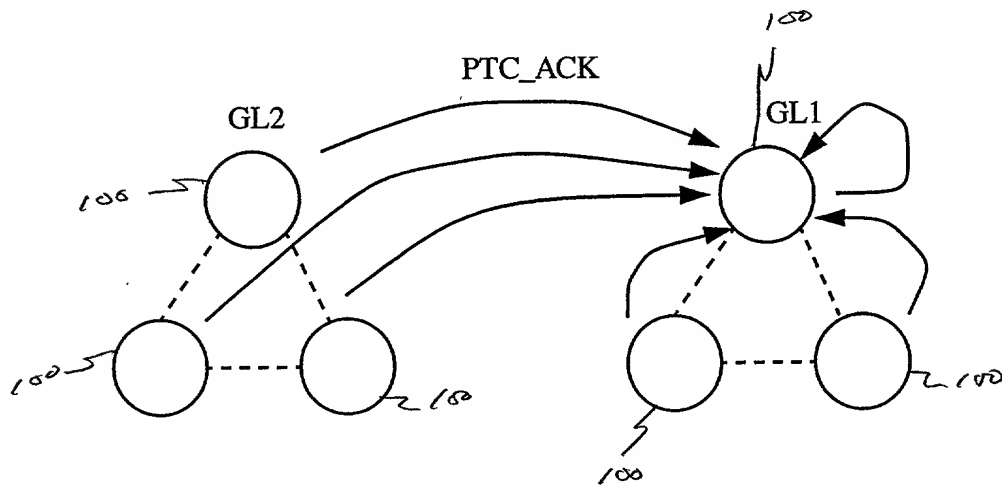


Figure 2d) JOIN Protocol: PTC_ACK message

4/30

P04920020016451

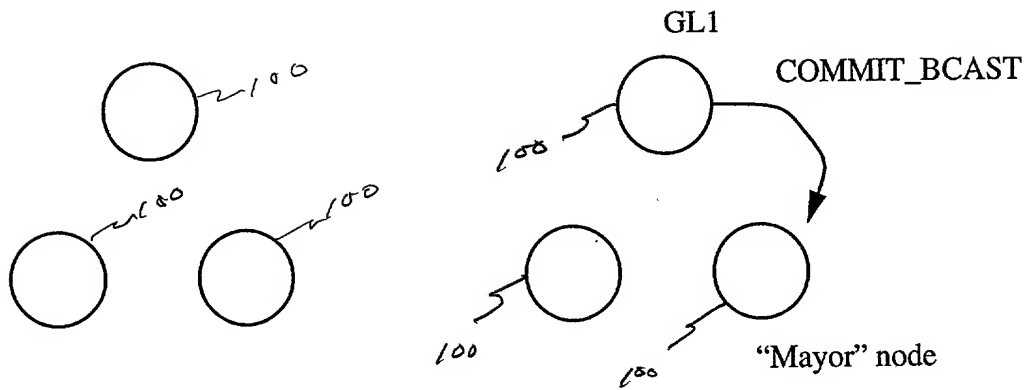


Figure 2e) JOIN Protocol: COMMIT_BCAST message

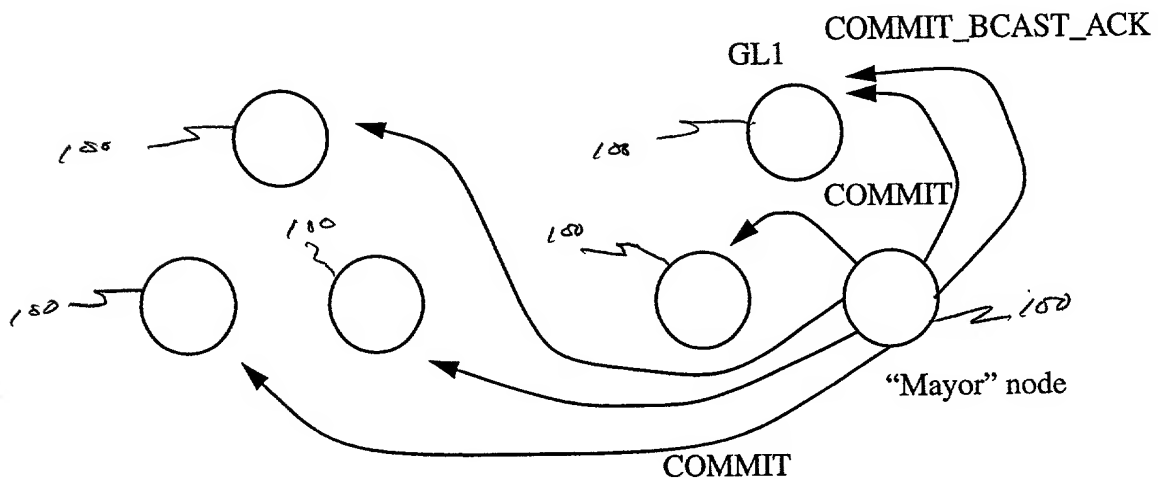


Figure 2f) JOIN Protocol: COMMIT and COMMIT_BCAST_ACK messages

5/30

Pou 9 2002 0016 451

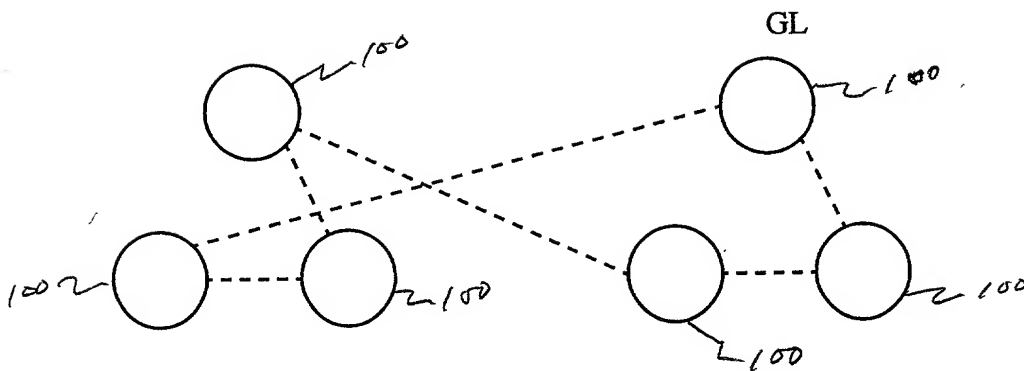


Figure 2g) JOIN Protocol: new group formed after completion of protocol

Figure 2: JOIN protocol

10073076-031502

6/30

Pou 920020016 US1

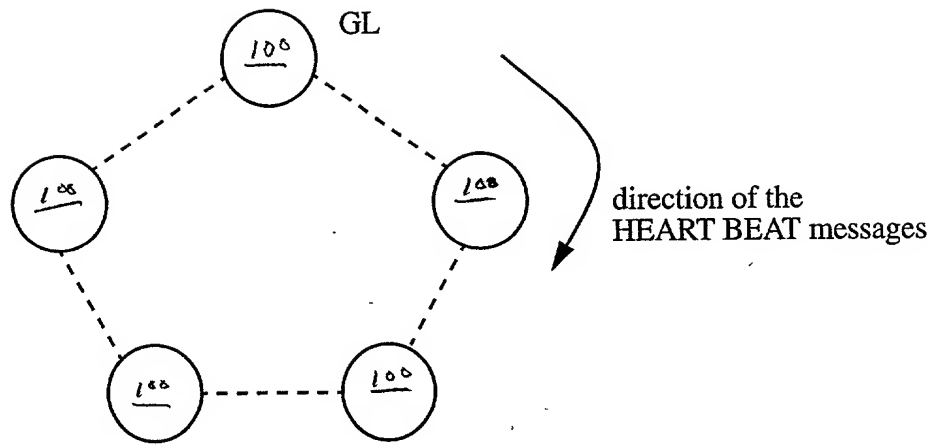


Figure 3a) DEATH Protocol: initial state: heartbeat ring

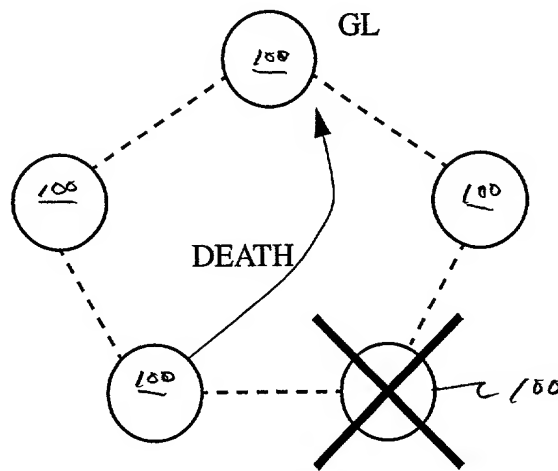


Figure 3b) DEATH Protocol: DEATH message

10078076-021502

7/30

P04920020016451

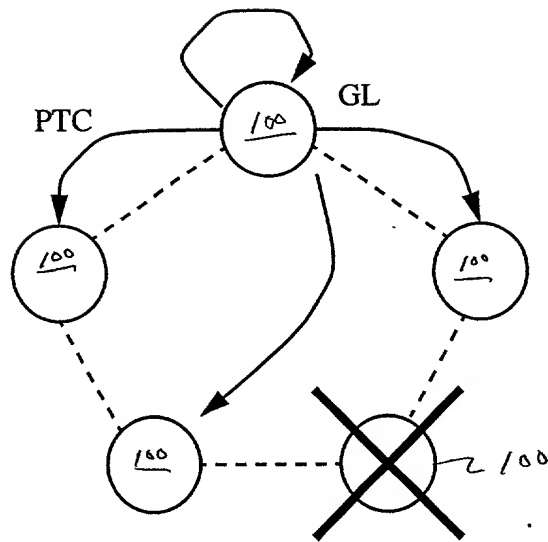


Figure 3c) DEATH Protocol: PTC message

Figure 3: DEATH protocol

10078076-021502

8/30
POU 920020016451

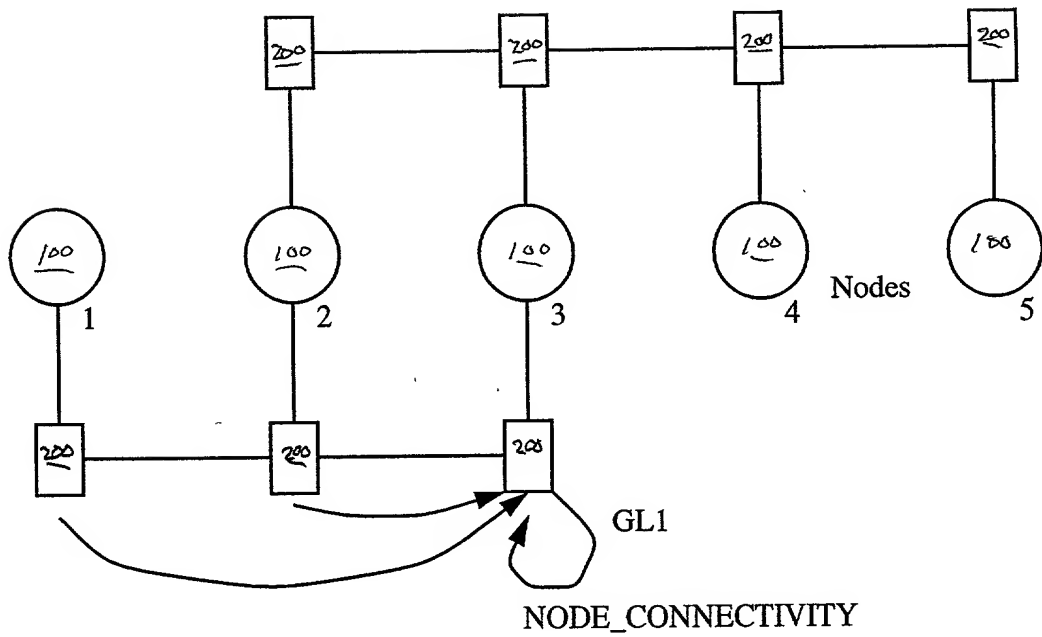


Figure 4a) Node Reachability Protocol: NODE_CONNECTIVITY message

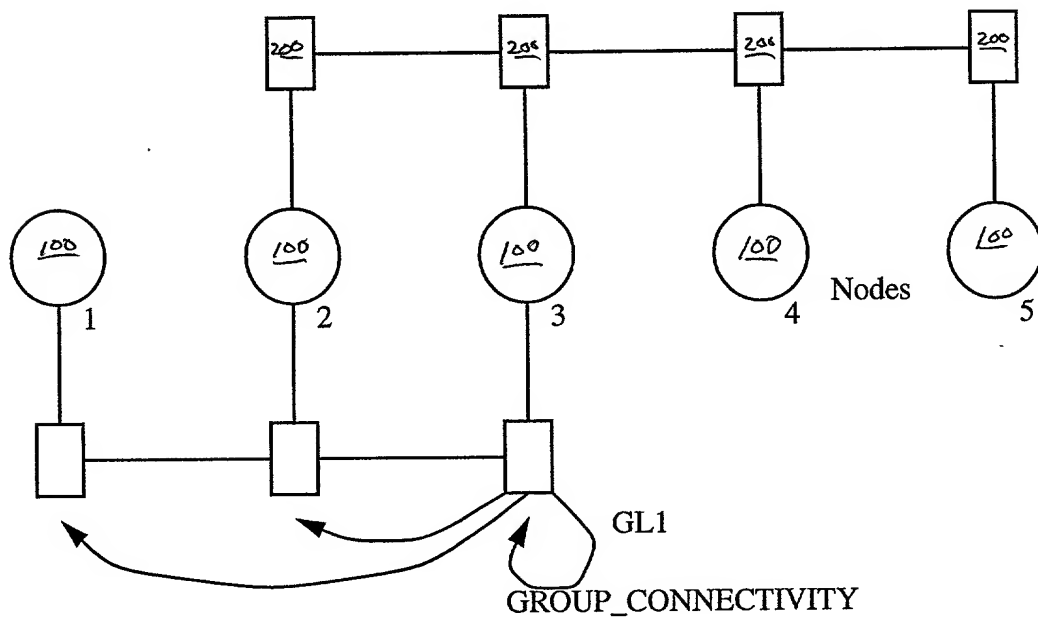


Figure 4b) Node Reachability Protocol: GROUP_CONNECTIVITY message

9/30

Pou920020016US1

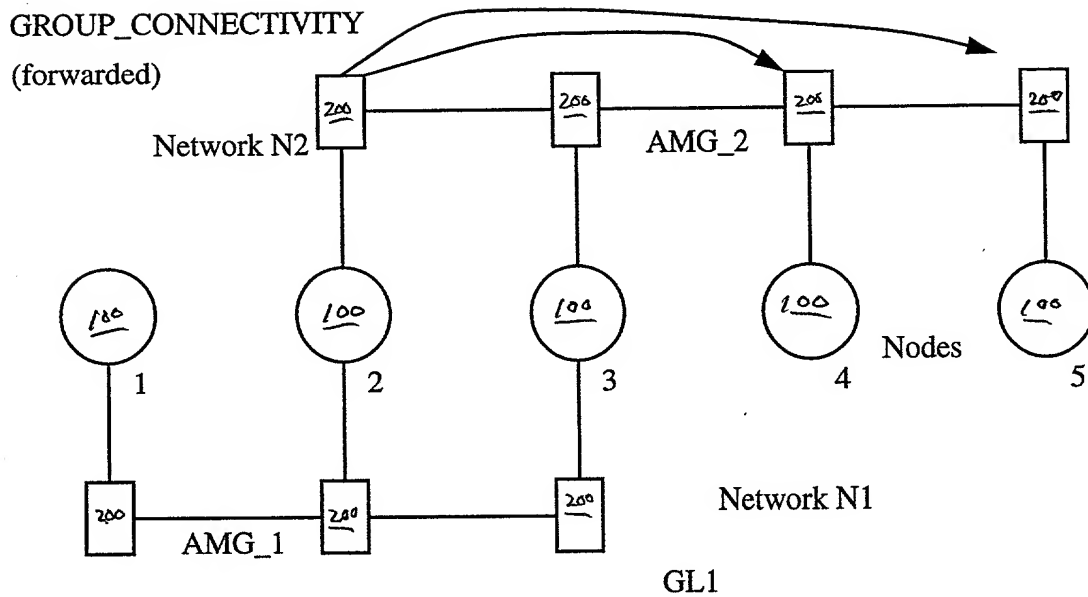
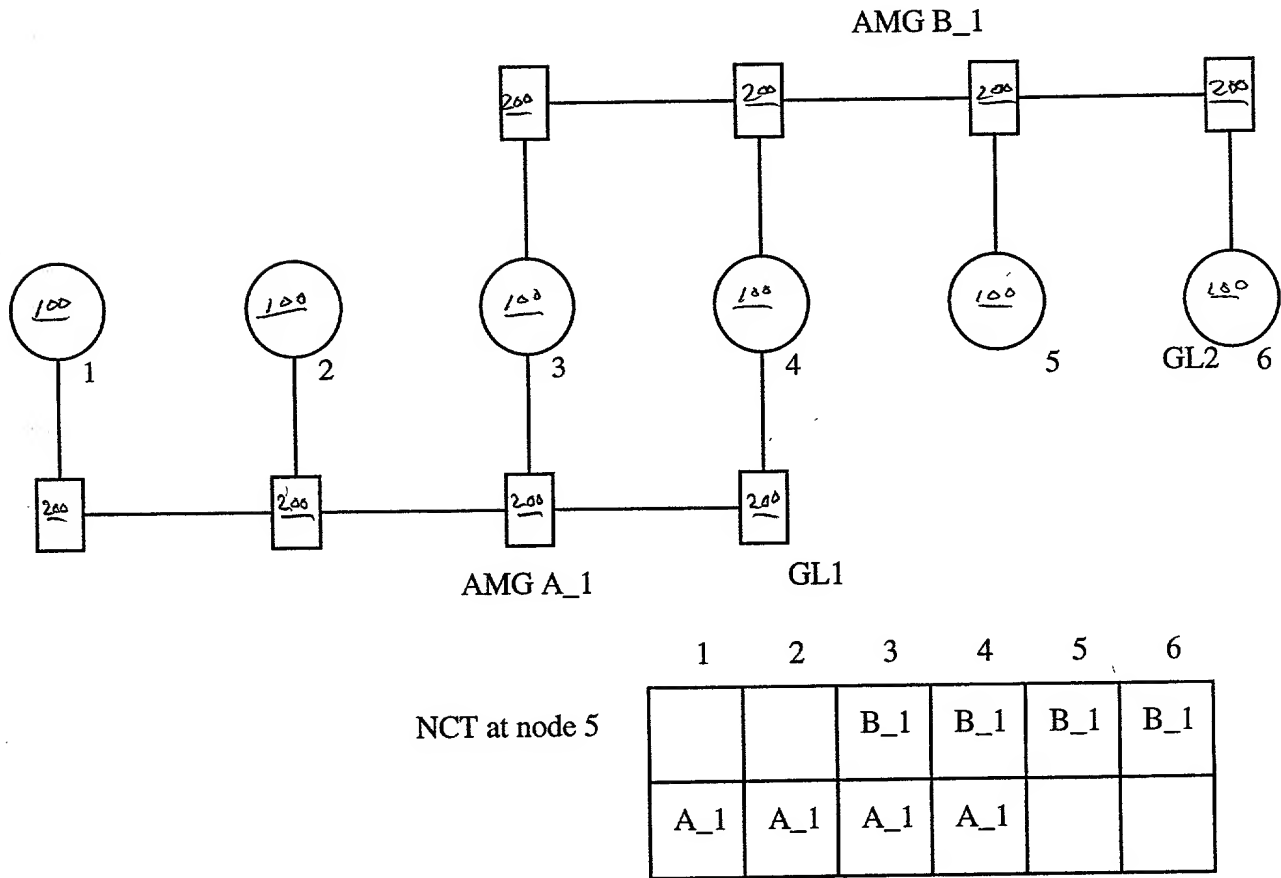


Figure 4c) Node Reachability Protocol: forwarding of GROUP_CONNECTIVITY message

Figure 4: Node reachability protocol: NODE_CONNECTIVITY and GROUP_CONNECTIVITY messages

10/30

P04920020016451

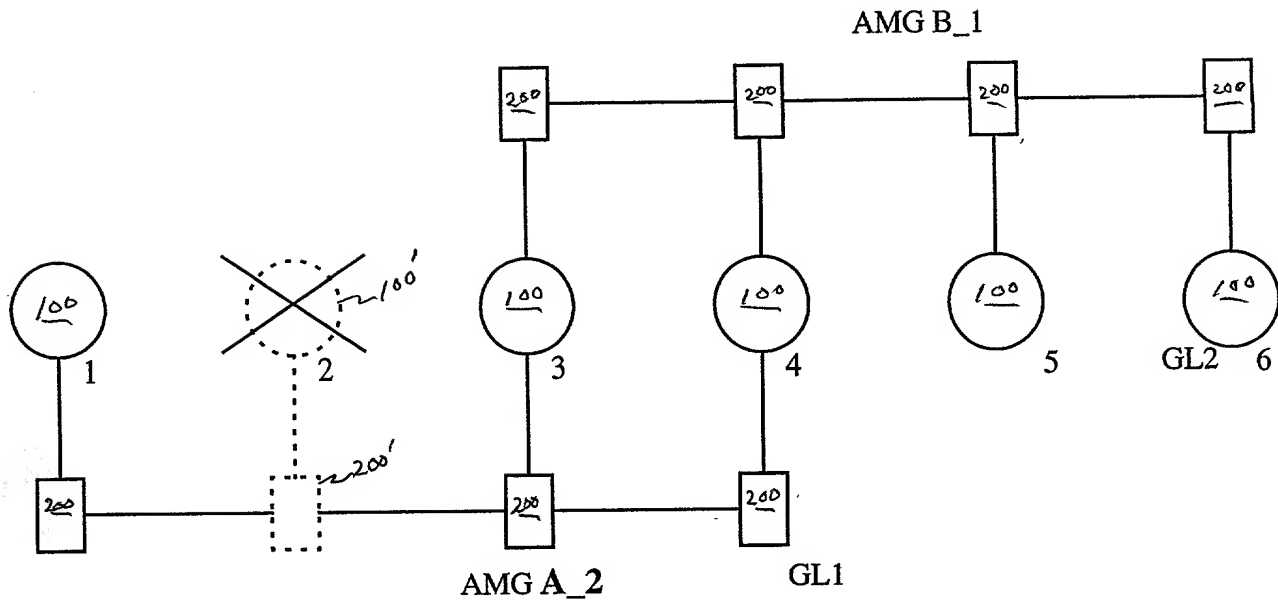


5a) Initial situation

Figure 5: Topology Propagation Scenario: node death

11/30

P04920020016451

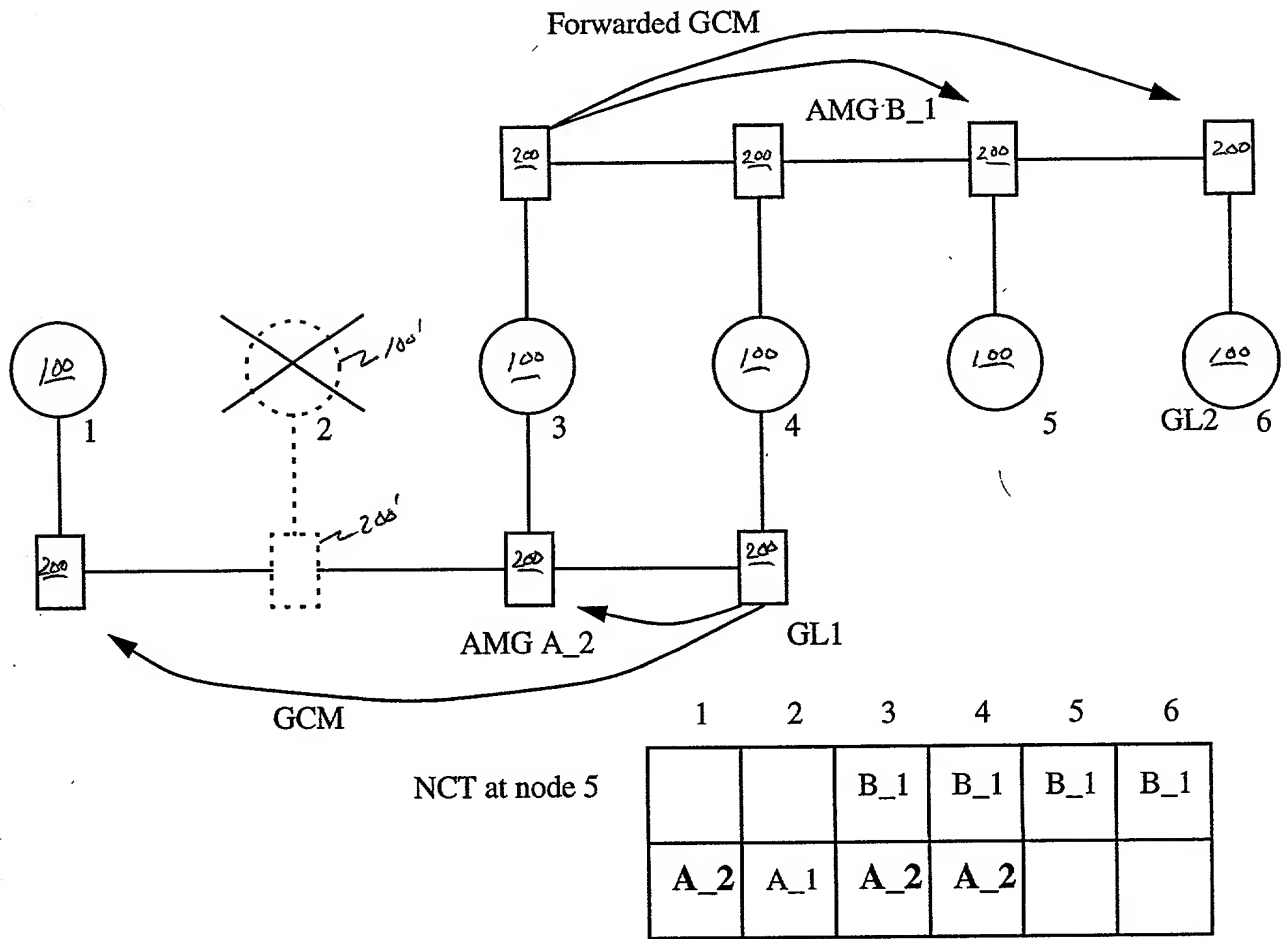


NCT at node 5

1	2	3	4	5	6
		B_1	B_1	B_1	B_1
A_1	A_1	A_1	A_1		

5b) Node 2 dies: Nodes 1, 3, and 4 form AMG A_2

12/30
 Pou920020016451



5c) GCM for AMG A_2 is propagated to all nodes

13/30

Pou920020016 u51

Network A: 10 seconds detection time
Network B: 40 seconds detection time

Nodes 1 and 2 are forming AMGs on networks A and B

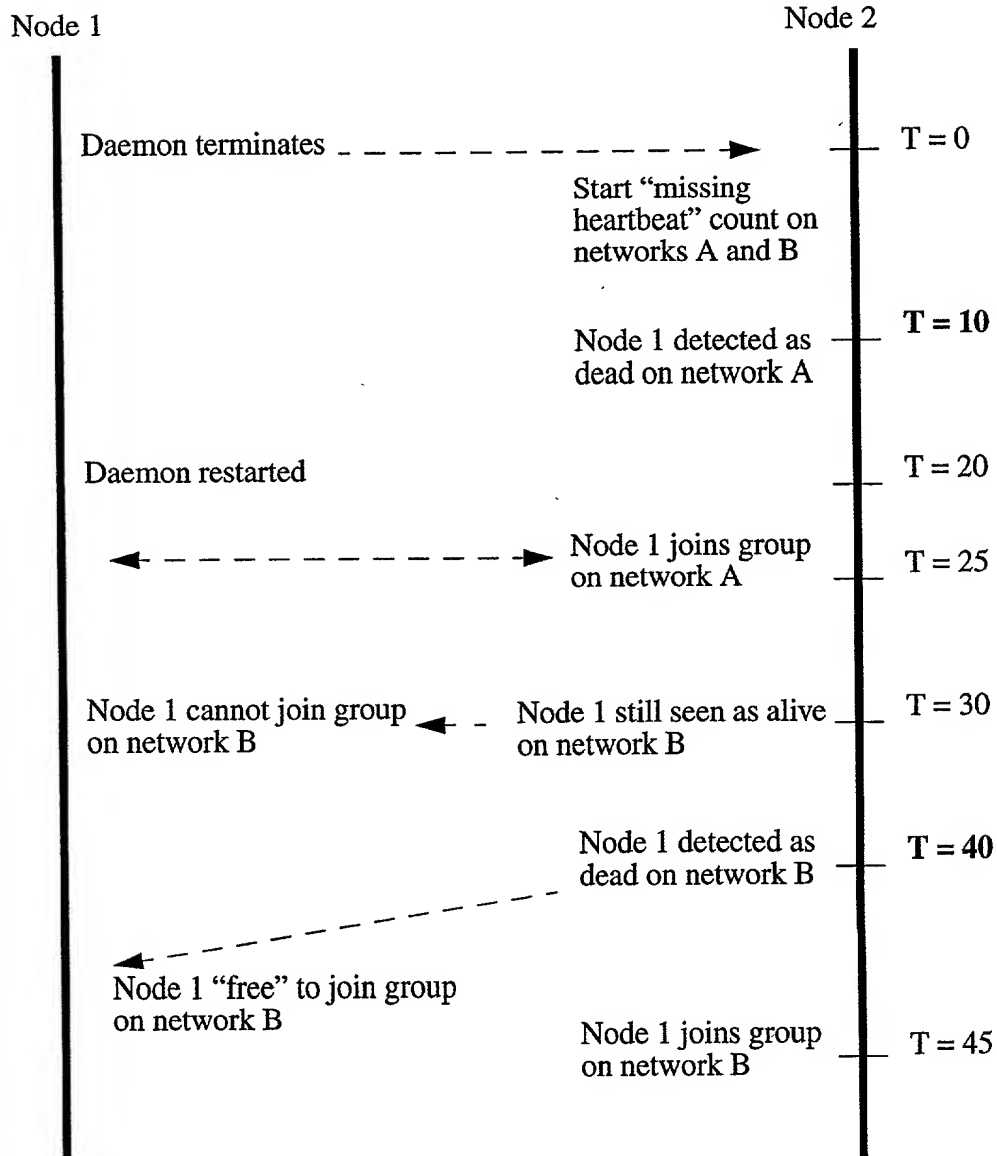


Figure 6 Inconsistency caused by quick daemon restart in the presence of different detection times for each network: the daemon on node 1 goes down and is restarted, but this is never detected by node 2.

14/30

P04920020016 US1

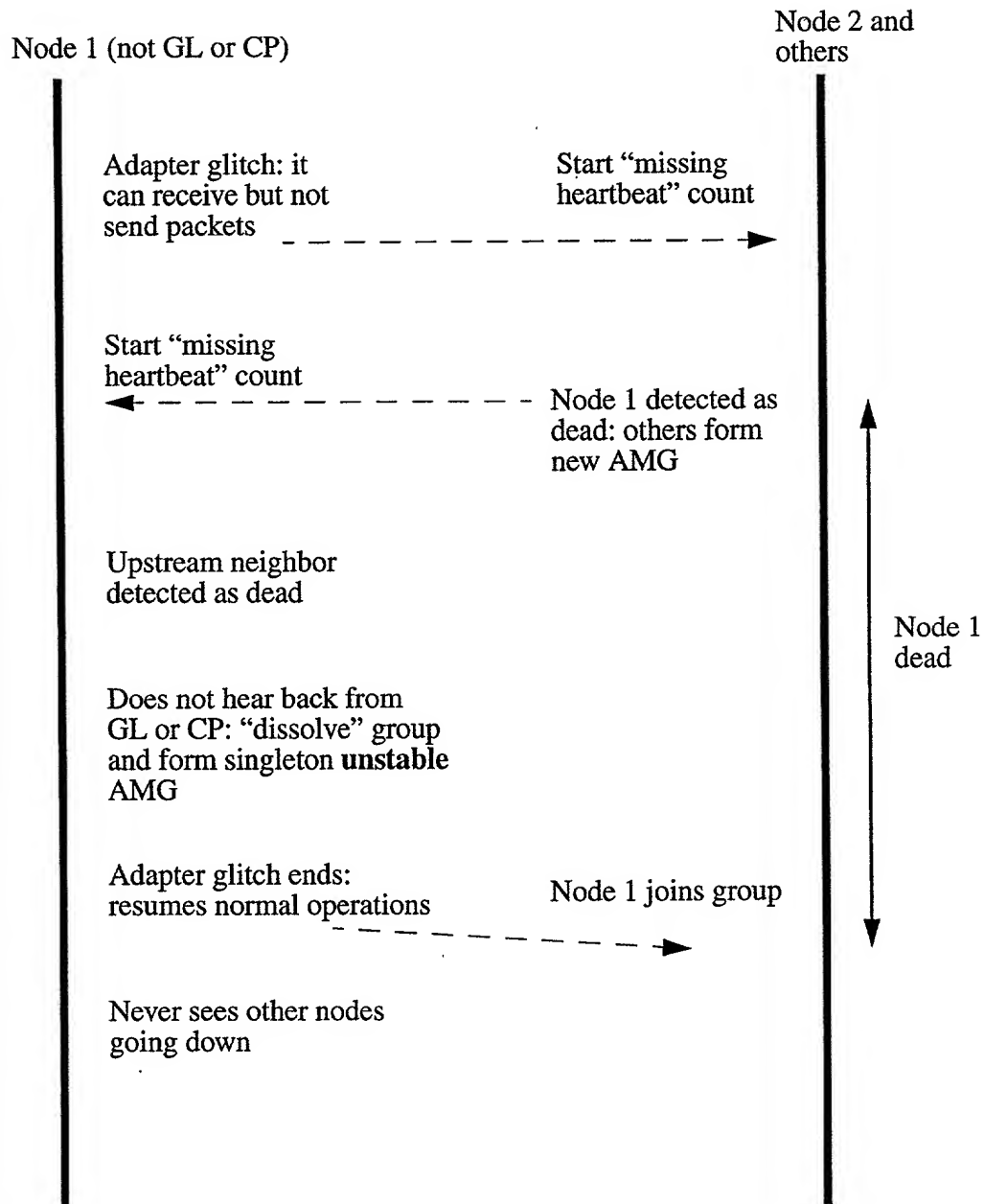


Figure 2) Inconsistency caused by temporary communication problem in an adapter: node 1 is not the GL or CP in its group. Node 1 never notices other nodes as down, though the others do see node 1 being unreachable.

15/30

P04920020016 US1

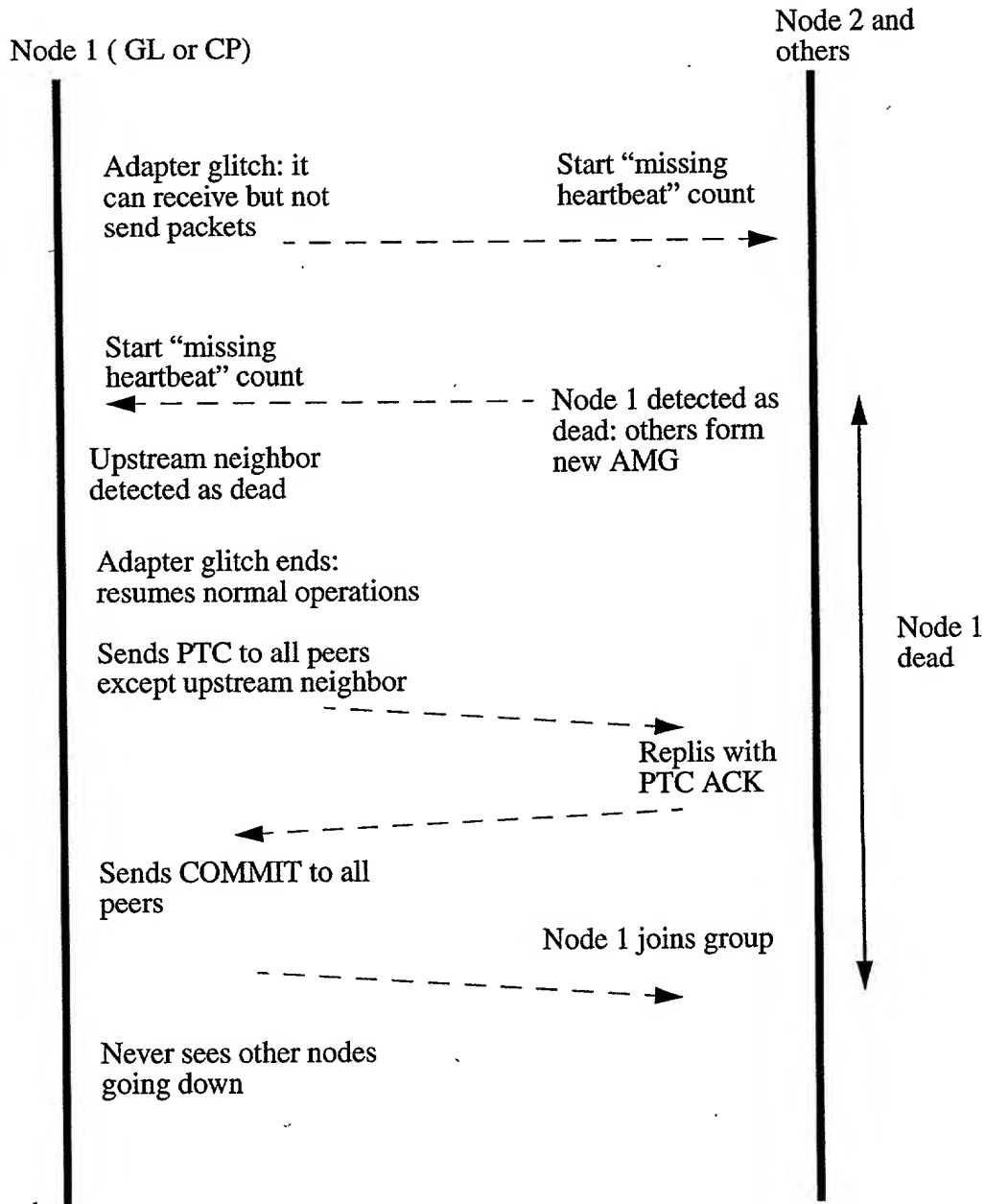
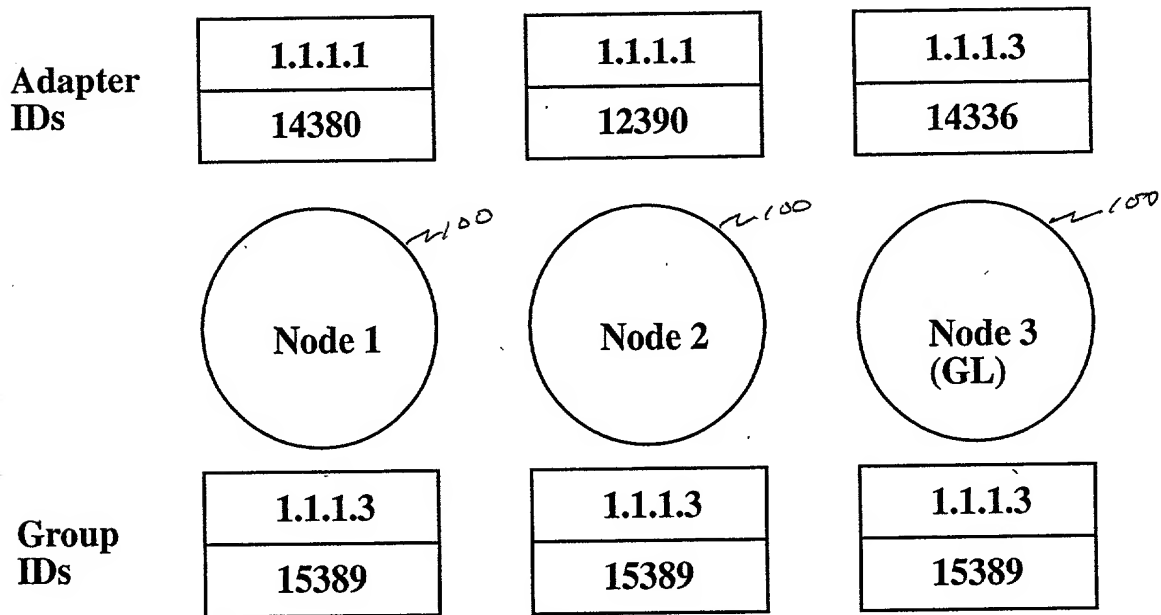


Figure 8 Inconsistency caused by temporary communication problem in an adapter: node 1 is the GL or CP in its group. Node 1 never sees the other nodes as unreachable, while the others do see node 1 as unreachable for a period.

16/30

P04920020016451



9

Figure 10) Adapter IDs and Group IDs. An adapter ID has the IP address of the adapter and an instance number. The Group ID has the IP address of the Group Leader and an instance number that changes each time the group changes.

17/30

Pou 920020016 451

Message Type
Source Adapter ID
Source Group ID
Destination Adapter ID
Destination Group ID
Payload

10078076.021503

10
Figure 10) Format of the protocol packets that are sent over the network

[REDACTED]

18/30

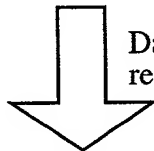
Pou 920020016 451

Node 1

1.1.1.1
7259

1.1.1.2
7820

1.1.1.2	1.1.1.1
7687	7259



Daemon at node 1 restarts

1.1.1.1
7901

1.1.1.1
7912

1.1.1.1
7901

Node 2

1.1.1.2
7687

1.1.1.2
7820

1.1.1.2	1.1.1.1
7687	7259

Adapter ID

Group ID

Group (AMG)

Adapter ID

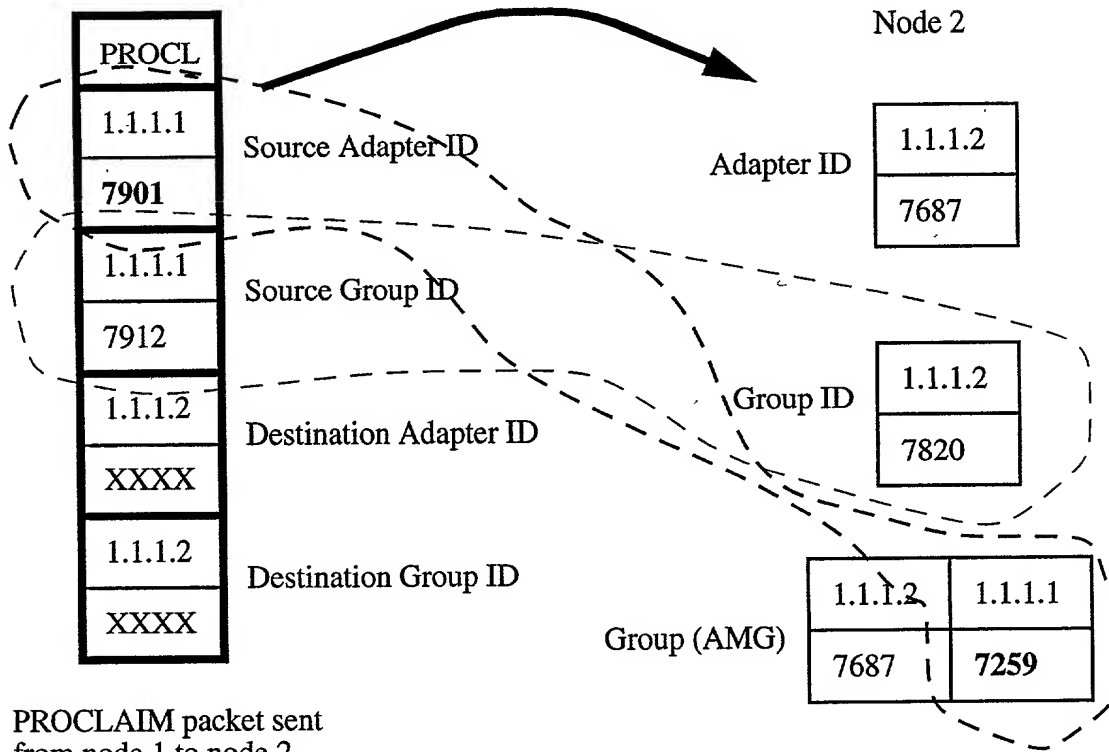
Group ID

Group (AMG)

Figure 18) Adapter and Group IDs when the daemon at node 1 terminates and is restarted.

19/30

P04920020016451



12
Figure 8) A "live" node detects that a remote daemon restarted. The Group ID of the message is different from node 2's, while the address of the sender is listed on node 2's group membership.

20/30

P04920020016 US1

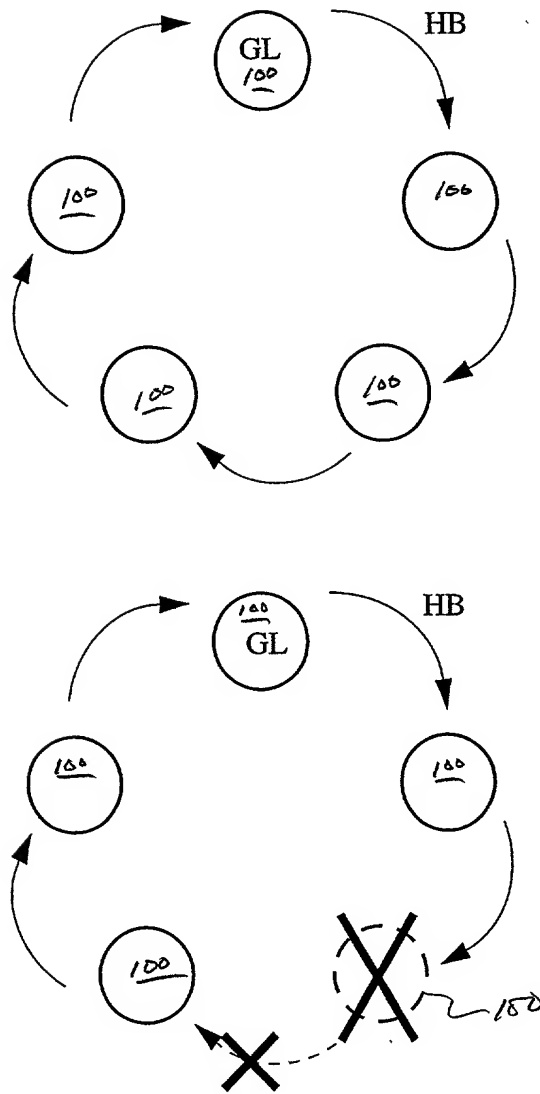
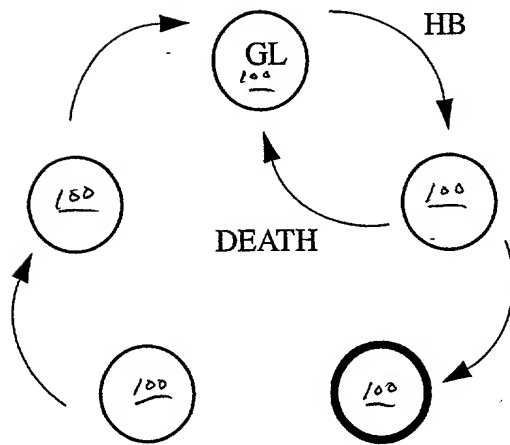
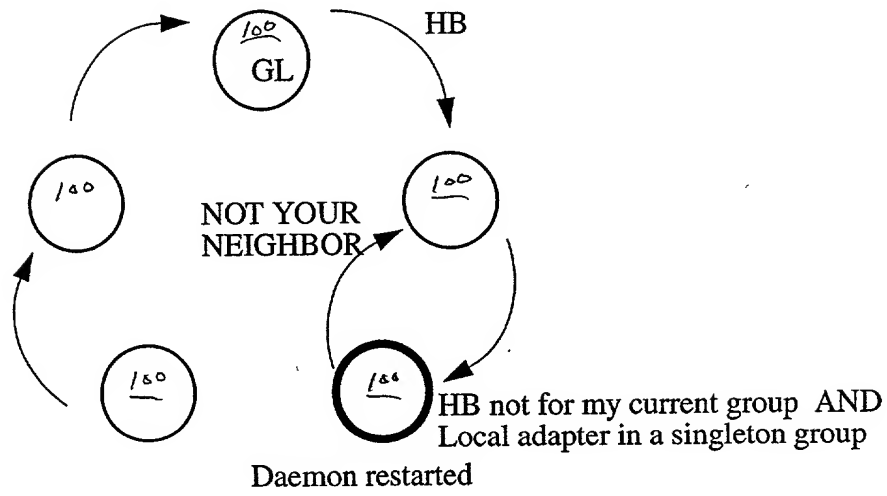


Figure 13a) A daemon that is restarted detects that a previous instance used to belong to an AMG because of heartbeat messages that it receives while in a singleton group.

21/30

Pou 920020016 US1



13
Figure 9b) Continuation

22/30

P00920020016 u51

Node 3 (GL)

Node 2

1.1.1.3
7687

Adapter ID

1.1.1.2
7687

1.1.1.3
7820

Group ID

1.1.1.3
7820

1.1.1.3	1.1.1.2	1.1.1.1
7687	7259	7228

Group (AMG)

1.1.1.3	1.1.1.2	1.1.1.1
7687	7259	7228

1.1.1.3	1.1.1.2	1.1.1.1
7687	7259	7228

last_stable_group

1.1.1.3	1.1.1.2	1.1.1.1
7687	7259	7228

Communication glitch
in node 3's adapter.

14

Figure 3a) Solution to the Quick Communication Interruption Problem. initial state: nodes 1,2, and 3 are part of the same AMG. Node 3's adapter suffers a temporary failure.

23/30

Pou 92002 0016 451

10078076 021502

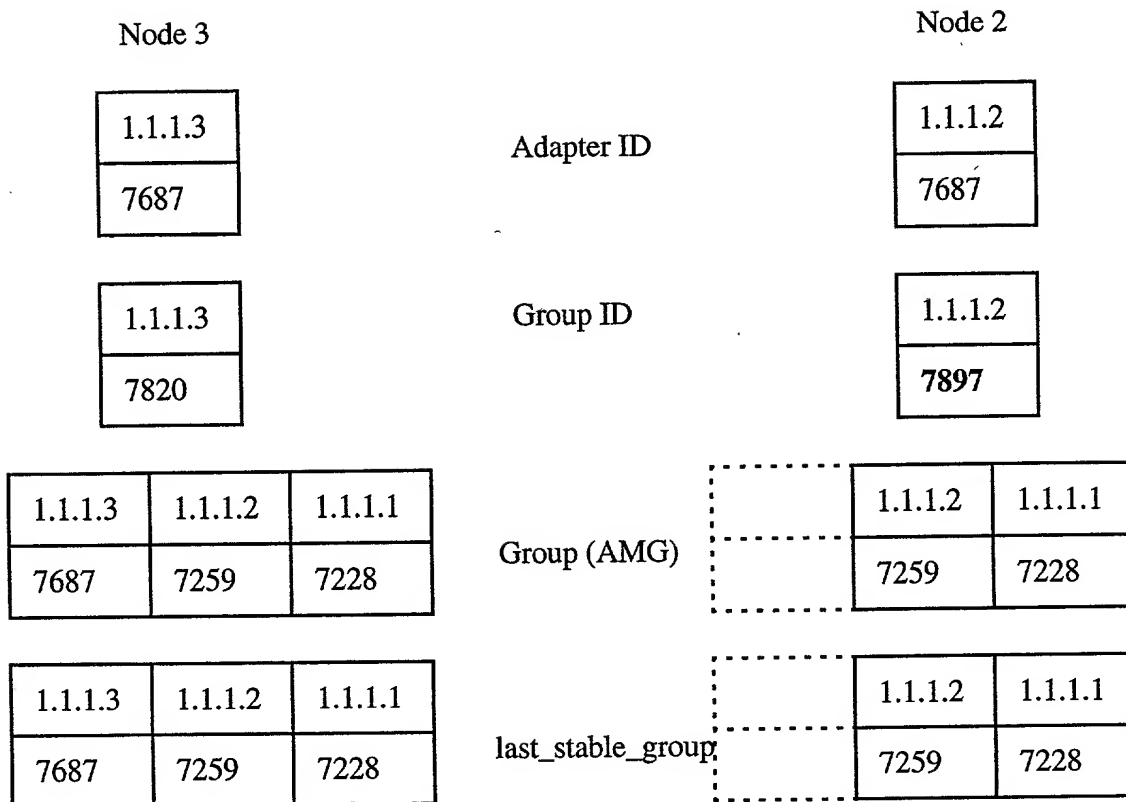
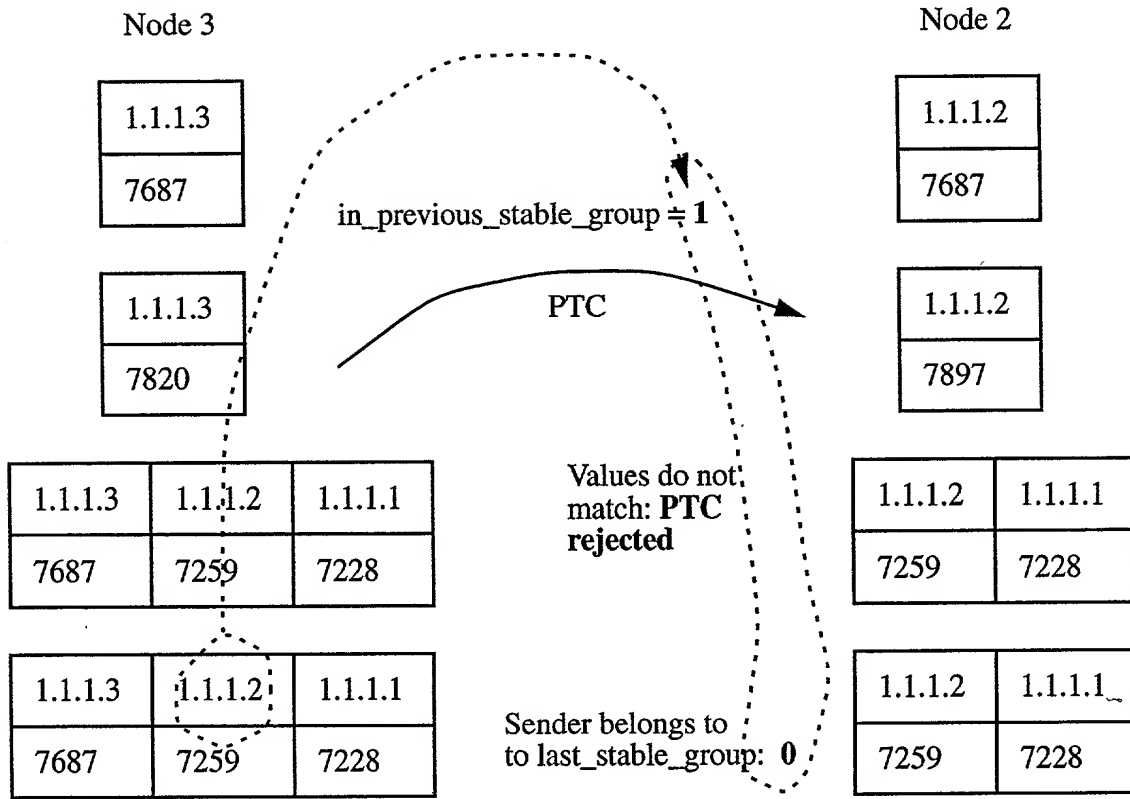


Figure 14b) Solution to the Quick Communication Interruption Problem. Node 3's adapter suffers a temporary failure. Node 2 commits a new AMG, while node 3 is still in the process of missing HBs from its neighbor

24/30

Pou920020016 u51



14
Figure 5c) Solution to the Quick Communication Interruption Problem. Node 3 sends a PTC when it stops receiving HBs from its upstream neighbor. The PTCs are rejected because of the discrepancy in the last_stable_group results.

25/30

Pou920020016 u51

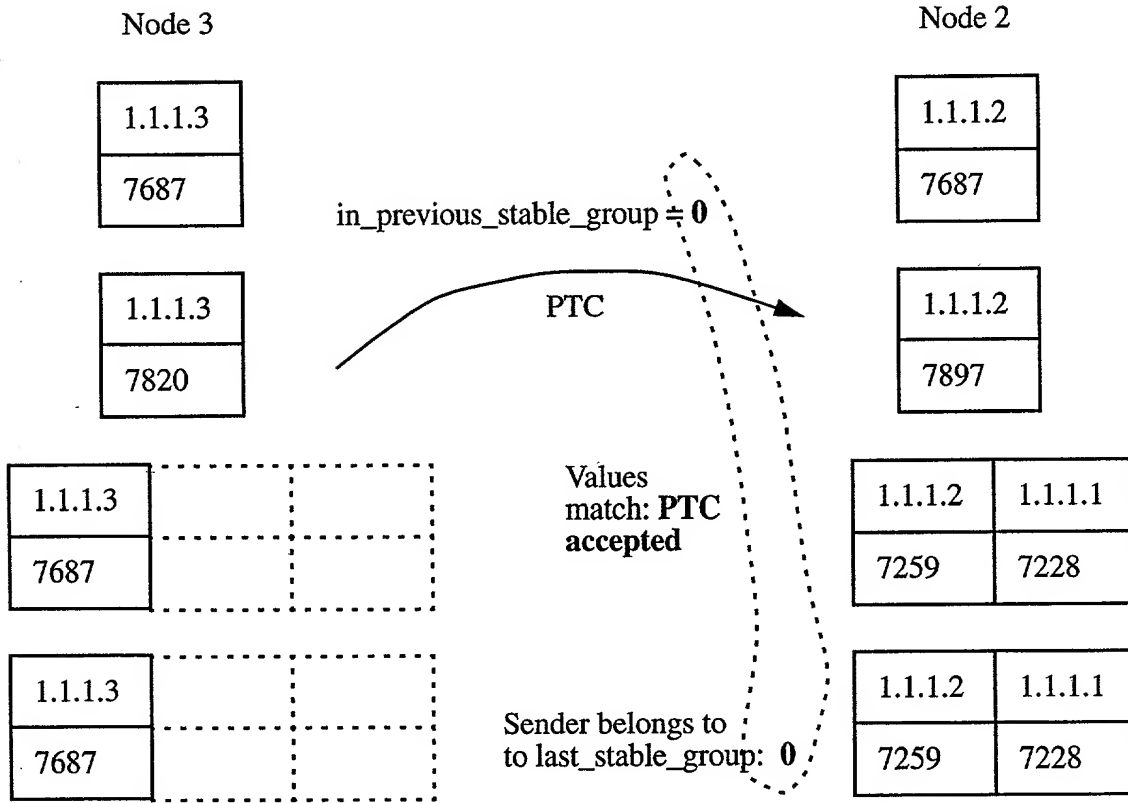


Figure 14d) Solution to the Quick Communication Interruption Problem. Since node 3 does not get replies to its PTC messages, it is forced to form a singleton group. At this point, it updates last_stable_group. From then on node 3's PTC are accepted again.

26/30

POU 92002 0016 451

Node 1

1.1.1.1
7228

Adapter ID

Node 3 (GL)

1.1.1.3
7687

Group ID

1.1.1.3
7820

1.1.1.3
7820

Group (AMG)

1.1.1.3	1.1.1.2	1.1.1.1
7687	7259	7228

1.1.1.3	1.1.1.2	1.1.1.1
7687	7259	7228

last_stable_group

1.1.1.3	1.1.1.2	1.1.1.1
7687	7259	7228

1.1.1.3	1.1.1.2	1.1.1.1
7687	7259	7228

Communication glitch
in node 1's adapter.

Figure 5a) Solution to the Quick Communication Interruption Problem. initial state: nodes 1,2, and 3 are part of the same AMG,. Node 1's adapter suffers a temporary failure.

27/30

Pou 920020016451

Node 1

1.1.1.1
7228

Adapter ID

Node 3

1.1.1.3
7687

Group ID

1.1.1.3
7820

1.1.1.3
7884

Group (AMG)

1.1.1.3	1.1.1.2	1.1.1.1
7687	7259	7228

1.1.1.3	1.1.1.2	
7687	7259	

last_stable_group

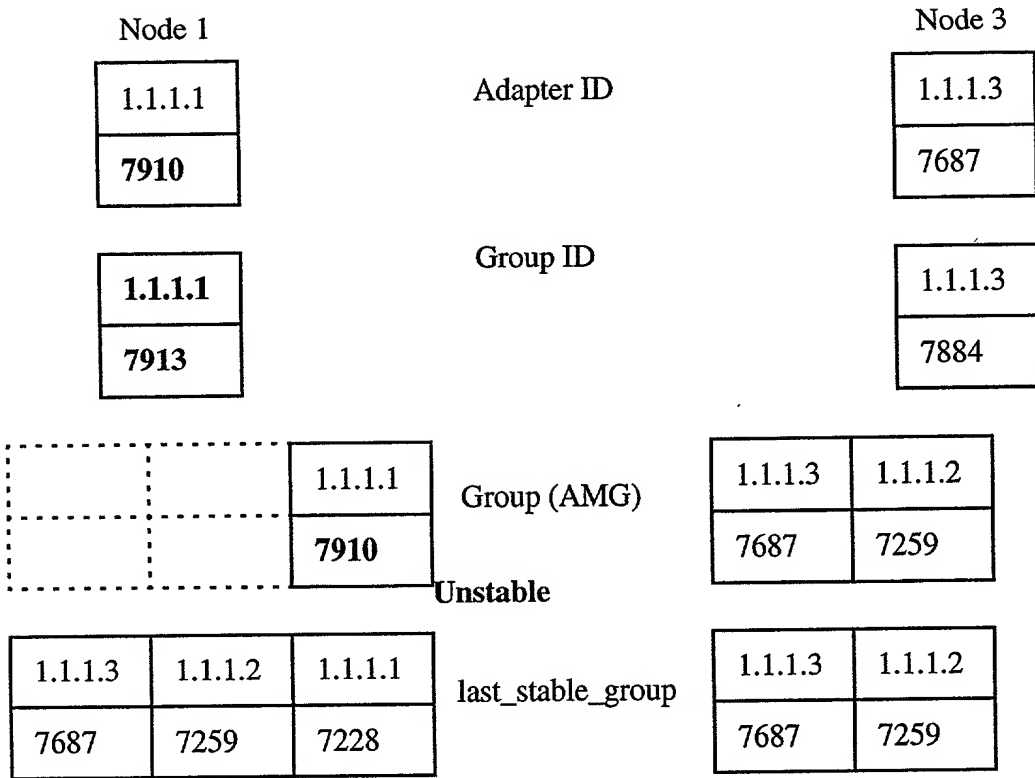
1.1.1.3	1.1.1.2	1.1.1.1
7687	7259	7228

1.1.1.3	1.1.1.2	
7687	7259	

Figure 5b) Solution to the Quick Communication Interruption Problem. Node 1's adapter suffers a temporary failure. Node 3 commits a new AMG, while node 1 is still in the process of missing HBs from its neighbor

28/30

Pou920020016 US1



15
Figure 15(c) Solution to the Quick Communication Interruption Problem. Node 1 dissolves its group and forms a singleton unstable group. Note that because the group is unstable, there is no change in last_stable_group.

29/30

Pou 920020016 US1

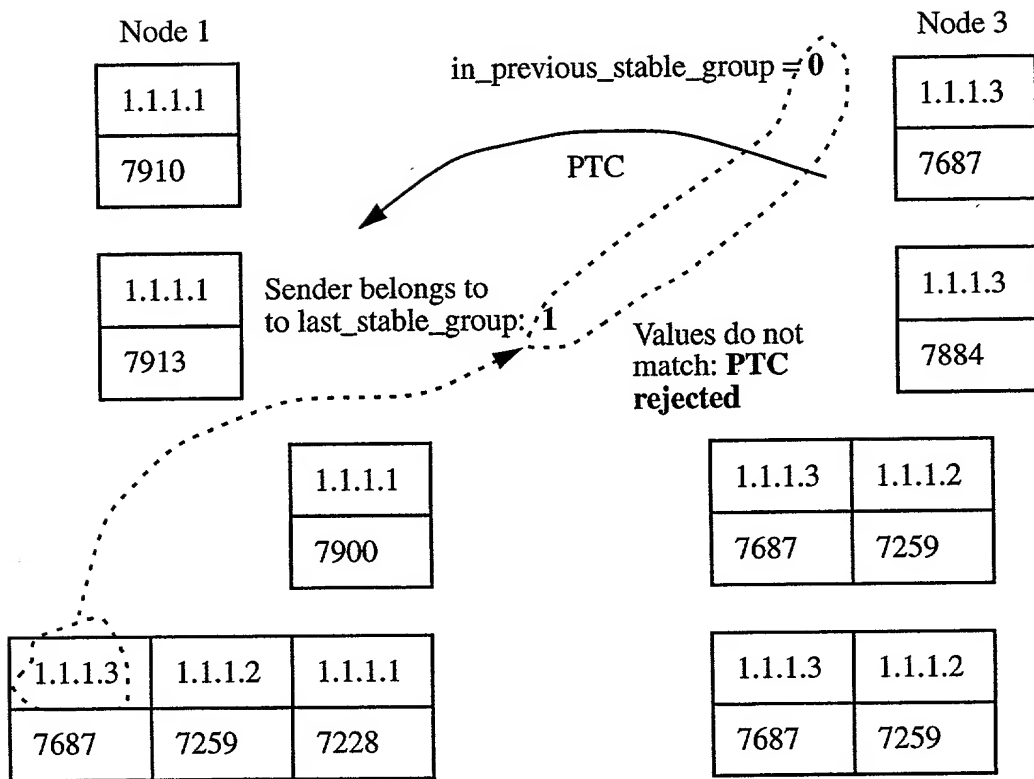


Figure 15d) Solution to the Quick Communication Interruption Problem. Node 3 sends a PTC when node 1 responds the PROCLAIM message with a JOIN. The PTCs are rejected because of the discrepancy in the last_stable_group results.

30/30

P0092002 0016 451

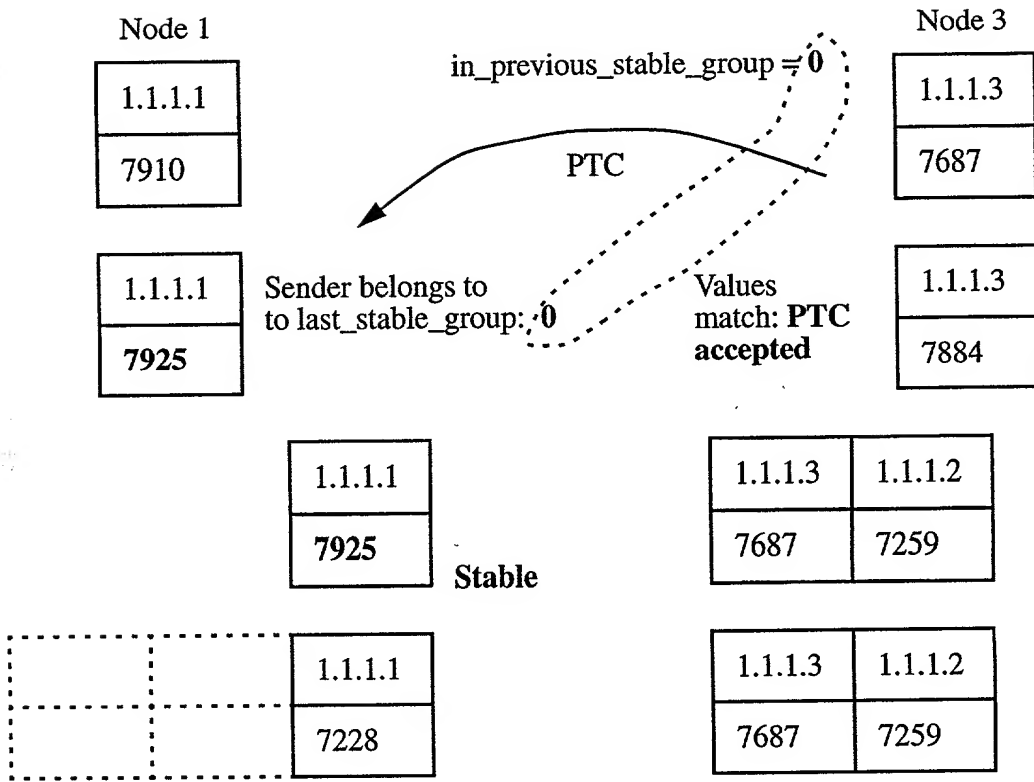


Figure 15e) Solution to the Quick Communication Interruption Problem. Since node 3 does not get replies to its PTC messages, it is eventually forced to form a singleton group. At this point, it updates last_stable_group. From then on node 3's PTC are accepted again.